



## Residential Permit Guidelines for Solar Photovoltaic (PV) Systems 2008 NEC Article 690

**Please note:** Building and Electrical permits are required for PV systems. The following information must accompany all building permit applications. Reviews will be conducted in intermediate track.

- 1) Basic site plan diagram identifying location of major components—not to scale. This is a simple diagram to show where the equipment is located with the equipment clearly shown and identified on the plan. If PV array is ground-mounted, clearly show that system will be mounted within allowable zoned setbacks. **(Two copies)**
- 2) Electric diagram showing all major field-installed electrical components, wire identification and sizing, and grounding. This diagram needs to have sufficient detail to call out the electrical components, the wire types and sizes, number of conductors, and conduit type and size where needed. This will typically include detailed module information, series/parallel configuration of modules, details of the Photovoltaic Output Circuit, wire type and size of module wiring, type and size of any junction or combiner boxes, approximate length of conductors in PV array, approximate length of conductors from junction box to the photovoltaic power source disconnecting means. Other important information includes equipment grounding of the PV array and system grounding of the inverter. It will also include specific information on the PV inverter and all associated wire in and out of the inverter. The utility disconnect type and location and the means of connection to the building electrical system should be clearly identified. **(Two copies)** *Sample diagrams on pages 6-9.*

### 3) Major component information:

#### a) Inverter information:

I. Model number and manufacturer's "cut sheets" for the specific model.

II. Listing. Is the inverter listed by a Nationally Recognized Testing Laboratory (NRTL) such as UL 1741 and labeled "Utility-Interactive"? If the utility interactive labeling is not provided, does the device comply with the requirements of IEEE Std. 929-2000 (ANSI) as verified by the instruction manual and validated by the listing agency. The 2008 NEC [690.5 (C)] now requires labeling;

**WARNING  
ELECTRICAL SHOCK HAZARD  
IF A GROUND FAULT IS INDICATED  
NORMALLY GROUNDED CONDUCTORS  
MAY BE UNGROUNDED AND ENERGIZED**

*This label is to appear on the inverter or near the ground fault indicator at a visible location*

III. Maximum continuous output power at 40°C

IV. DC input voltage range

V. AC output voltage range

b) *Module information:*

- I. Manufacturer's "cut sheets" for the specific model.
- II. Listing. The module(s) should be listed to UL 1703.  
**Explanation: All electrical devices and components must be listed to UL® (Underwriters Laboratories) North American Standards**
- III. Open-circuit voltage. Note: When open-circuit voltage temperature coefficients are supplied in the instructions for listed PV modules, they shall be used to calculate the maximum PV system voltage as required by [110.3(B)] instead of using Table [690.7]
- IV. Maximum permissible system voltage. [690.7(A-E)]
- V. Short-circuit current rating.
- VI. Maximum series fuse rating.
- VII. Maximum power at Standard Test Conditions.
- VIII. Operating voltage.
- IX. Operating current.

*Alternating-Current Photovoltaic Modules:*

Alternating-current modules shall be marked with identification of terminals or leads and with identification of the following ratings:

- I. Nominal operating ac voltage.
- II. Nominal operating ac frequency.
- III. Maximum ac power.
- IV. Maximum ac current.
- V. Maximum overcurrent device rating for ac module protection.

c) *Battery information (if used):*

- I. Manufacturer's "cut sheets" for the specific model. Note storage and venting requirements.
- II. Nominal battery voltage for the system.

**4) Array information:**

- a) *Number of modules in series, number of parallel source circuits, and total number of modules.*
- b) *Operating voltage (sum of series modules operating voltage in source circuit).*
- c) *Operating current (sum of parallel source circuit operating currents). [690.8]*

d) *Maximum system voltage.* [690.7]

e) *Short-circuit current rating.* [110.10]

## 5) Wiring and Overcurrent Protection:

### a) *Wire Type:*

PV module interconnections should be 90°C wet-rated conductors.

Allowable wire types are as follows:

USE-2 single conductor cable for exposed applications and single conductor cable listed and labeled for PV use. Type TC multiconductor cable for exposed applications with THWN-2 or XHHW-2 or RHW-2 or equivalent 90°C wet-rated conductors in the cable. Type THWN-2 or XHHW-2 or RHW-2 or equivalent 90°C wet-rated conductors in high temperature conduit (conduit rated for a minimum of 75°C wet conditions).

### b) *Conductor Ampacity:*

Correct maximum current and ampacity calculations should be provided for each circuit. (Ampacity of conductors must be sufficient for application) [690.8]

I. The maximum PV source circuit current is the sum of parallel module rated short circuit currents multiplied by 125 percent [690.8(A)(1)].

II. The minimum source circuit conductor ampacity is 125 percent of the maximum PV source circuit current [690.8(B)(1)].

III. Minimum photovoltaic output circuit conductor ampacity is the sum of the maximum current of the parallel source circuits X1.25 [690.8(B)(1)]. Calculating ampacity of conductors used for the PV output circuit can be an involved process.

IV. Minimum inverter output circuit conductor ampacity must be equal to or greater than the inverter continuous output current rating times 1.25. *FPN [690.8 (A)] Where the requirements of [690.8(A)(1)&(B)(1)] are both applied, the resulting multiplication factor is 156%.*

### c) *Overcurrent protection:* Necessary fuses or circuit breakers must be properly sized and specified for each circuit.

I. Source circuit overcurrent protection must be sized so that both the PV module and the conductor from the module to the overcurrent device are properly protected [690.9 (A), 240.15 (A)]. PV modules must be protected so that the maximum series fuse rating, printed on the listing label, is not exceeded. The module may be protected either by installing fuses or circuit breakers in a series string of modules or by the design of the PV system. Inverters listed with a Maximum utility back feed current that is well above 1 amp (typically equal to the maximum allowable output overcurrent protection) must be assumed to provide back feed current to the PV array. Each source circuit must have overcurrent protection that is greater than or equal to the minimum PV Source Circuit current rating and less than or equal to the maximum series fuse rating.

For an inverter listed with a Maximum utility back feed current that is zero, two source circuits can be connected to the inverter without requiring overcurrent protection on either circuit. [690.9 (A) exceptions (a)&(b)]

II. Storage Battery (if used) overcurrent protection must have a sufficient voltage and ampere-interrupt rating to withstand the operating conditions of the battery system [480.4]. Article [480.5] covers the necessary means of disconnect.

III. Inverter Output Circuit overcurrent protection should be sized and protected according to the manufacturers directions and Article [240].

IV. NEC [690.64 (A) & (B)] covers the requirements for Point of Connection of a *utility interactive* PV inverter to the building electrical system. The most common method of connection is through a dedicated circuit breaker to a panel busbar. The sum of the overcurrent devices feeding a busbar or conductor can be up to 120% of the busbar or conductor rating. [690.64 (B)(2)]

#### 6) Provisions for the photovoltaic power source disconnecting means:

The 2008 NEC states in [690.14(C)(1)], *“Location. The photovoltaic disconnecting means shall be installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the system conductors... The photovoltaic system disconnecting means shall not be installed in bathrooms.”*

I. Readily accessible—[Article 100] states, *“Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.”*

II. Readily accessible provision is primarily for emergency operation. If the disconnect is not mounted in close proximity of the service entrance disconnect (usually within 10 feet of the meter location or service disconnect switch), then a diagram or directory must be provided to clearly identify where the disconnect is located. NEC [690.14 (C)(2)] requires each PV disconnect be permanently marked to identify it as a PV disconnect.

III. A rooftop disconnect on a residential roof will normally not qualify as a readily accessible disconnect. A new exception to this requirement has been added to provide additional clarification for residential and building integrated PV systems. [690.14 (C)(1) exception] This exception reads:

***“Exception: Installations that comply with [690.31(E)] shall be permitted to have the disconnecting means located remote from the point of entry of the system conductors.”***  
[690.31(E)] states: *“(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building. Where direct current photovoltaic source or output circuits of a utility-interactive inverter from a building-integrated or other photovoltaic system are run inside a building or structure, they shall be contained in metallic raceways or metal enclosures from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means. The disconnecting means shall comply with [690.14(A) through 690.14(D)].”*

## 7) Grounding:

The NEC [690.41] requires all systems operating above 50 volts have one conductor referenced to ground unless the system complies with the requirements of [690.35 (A-G)] for ungrounded PV arrays. **All devices and components of grounding/bonding system must be listed for use.**

a) *Equipment grounding conductor sizing.* [690.45] The size of the equipment grounding conductor is dependent on whether the system has ground fault protection (GFP) equipment or not. The provisions for GFP equipment are stated in [690.5]. Many residential inverters have GFP equipment integral to the inverter and require that the PV array be grounded at the inverter only.

I. Systems without ground fault protection equipment. The NEC requires that equipment grounding conductors for systems without GFP equipment have an ampacity of at least two (2) times the temperature and conduit fill corrected circuit conductor ampacity.

II. Systems with ground fault protection equipment. Size equipment grounding conductor according to NEC [Table 250.122].

III. DC System: Size grounding electrode conductor according to NEC [250.166].

## 8) Array Mounting information: **You will need this information to obtain your building permit**

I. Provide two copies of the site plan showing the location of the house and PV equipment.

II. Provide two copies of the array layout and the supporting structure. ***If roof mounted;*** show anchorage to the roof and framing structure and schematic elevations. Identify methods of sealing all roof penetrations. ***If ground or pole mounted;*** show array supports, connection details, framing members, and foundation posts and footings. In either case the plans showing the supporting structure details must be signed and sealed by a Maryland Licensed Professional Engineer certifying the design is in accordance with the applicable codes in Montgomery County, MD.

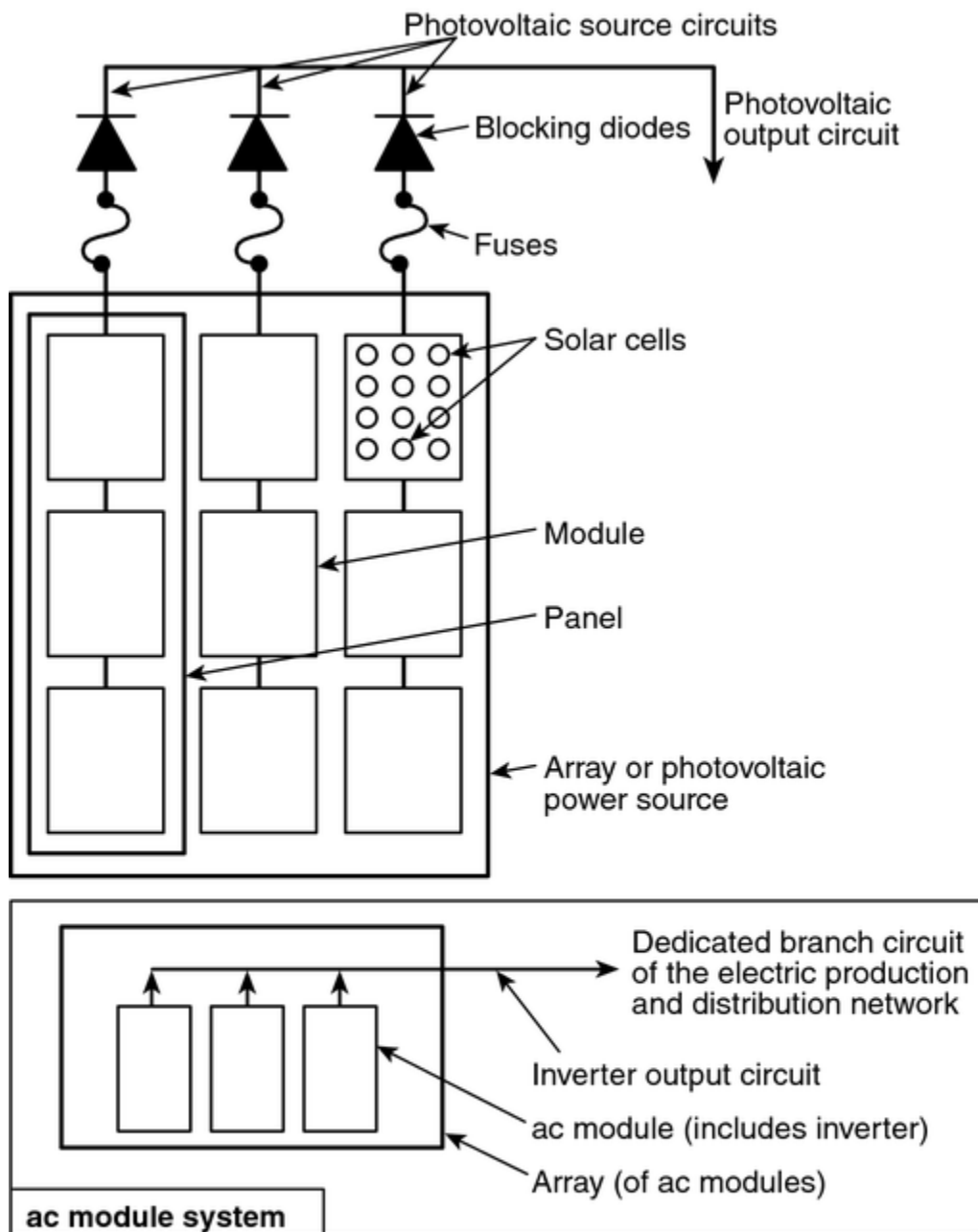
## 9) Inspections:

a) *Building permit.*

- I. Footing, inspection code 001. (If applicable)
- II. Framing, inspection code 004. (If applicable)
- III. Final, inspection code 251.

b) *Electrical permit.*

- I. Concealment, inspection code 104 (For wiring in walls, ceilings and trenches).
- II. Final, inspection code 251. Installer shall provide to the inspector photos depicting the array support connections, all electrical connectors, all ground connections, all conductor supports, and all sealed roof penetrations for all components that are not “readily accessible” (requiring ladder access).

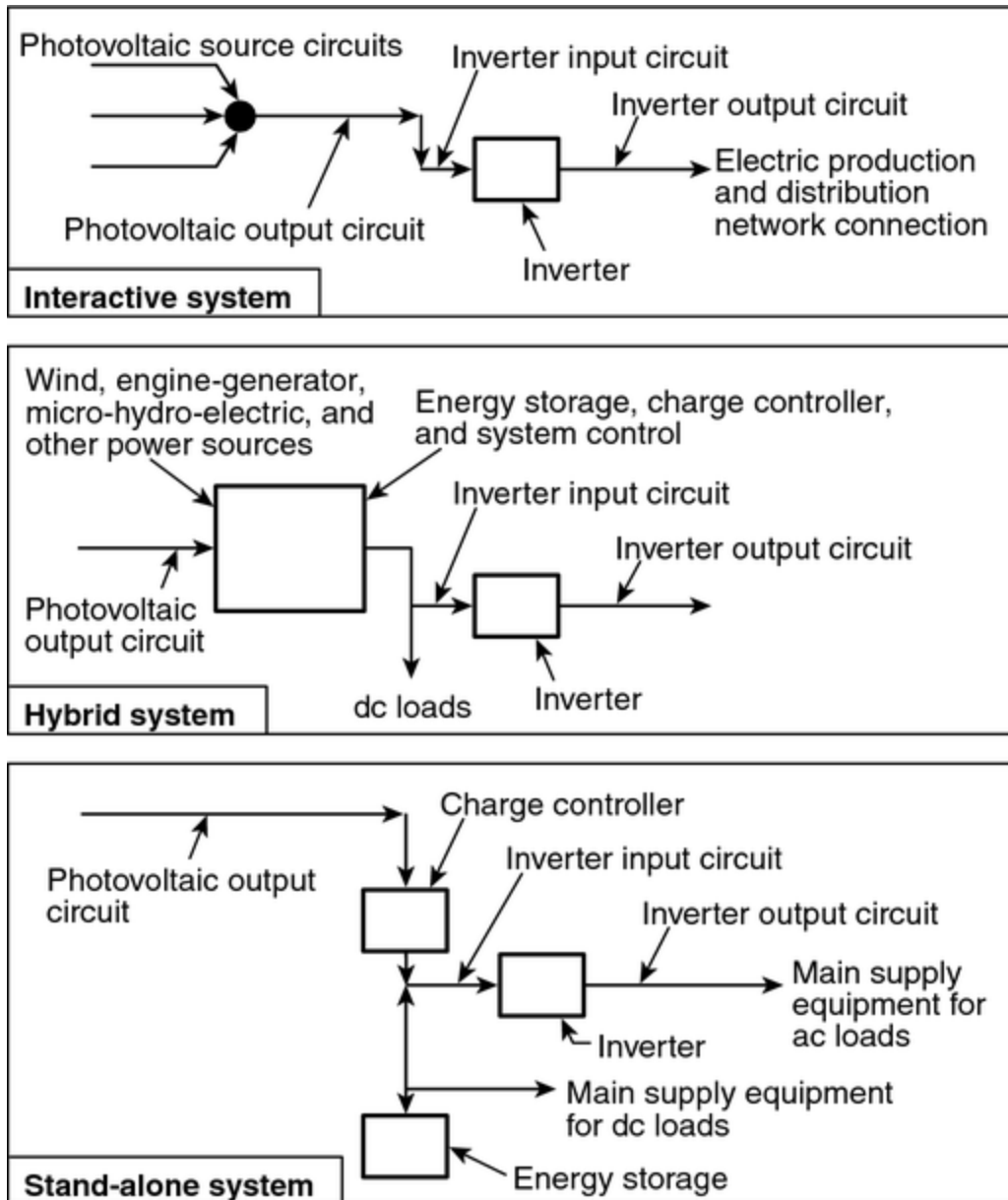


**Notes:**

1. These diagrams are intended to be a means of identification for photovoltaic system components, circuits, and connections.
2. Disconnecting means required by Article 690, Part III, are not shown.
3. System grounding and equipment grounding are not shown. See Article 690, Part V.

Figure 690.1(A) Identification of Solar Photovoltaic System Components.

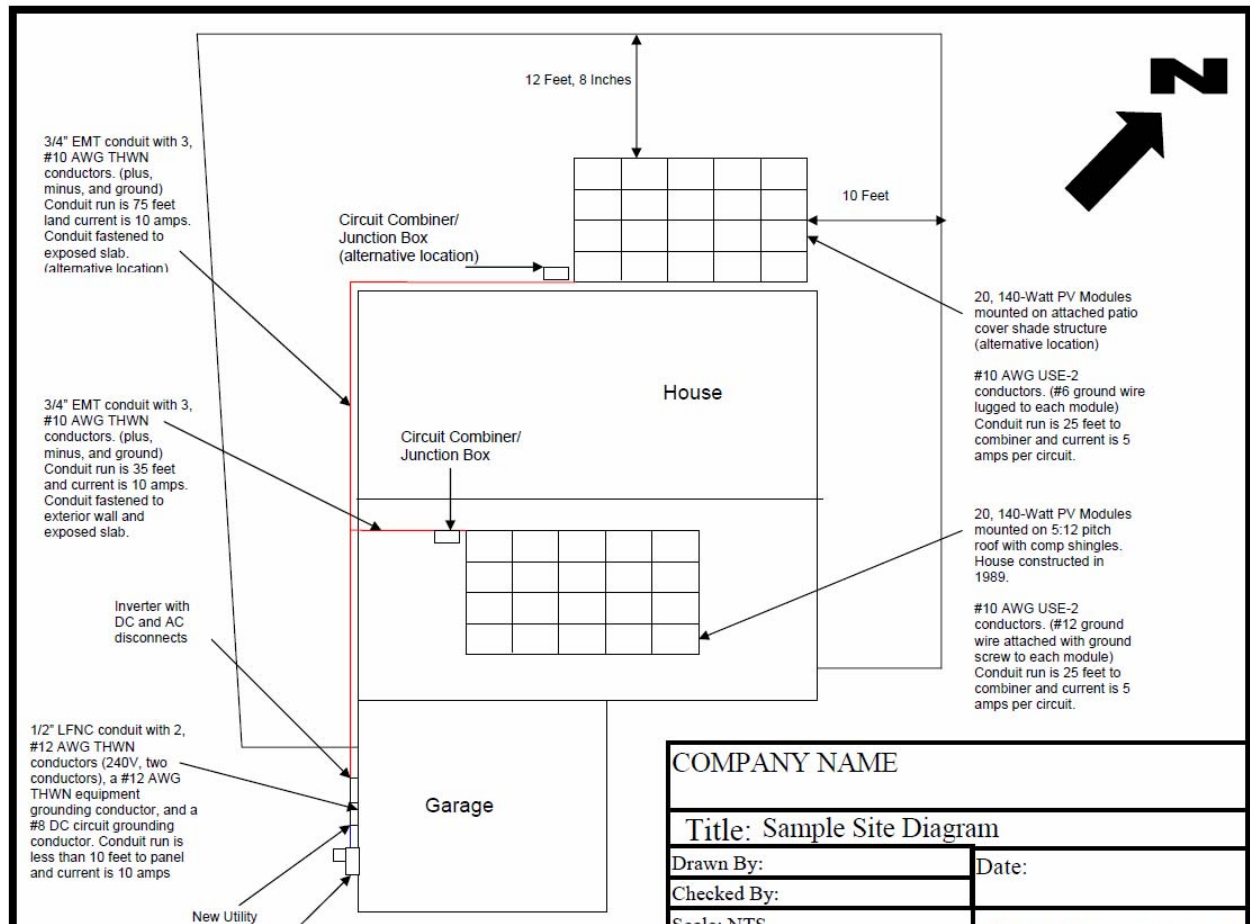
### Sample of Electrical Diagram (From NEC)



#### Notes:

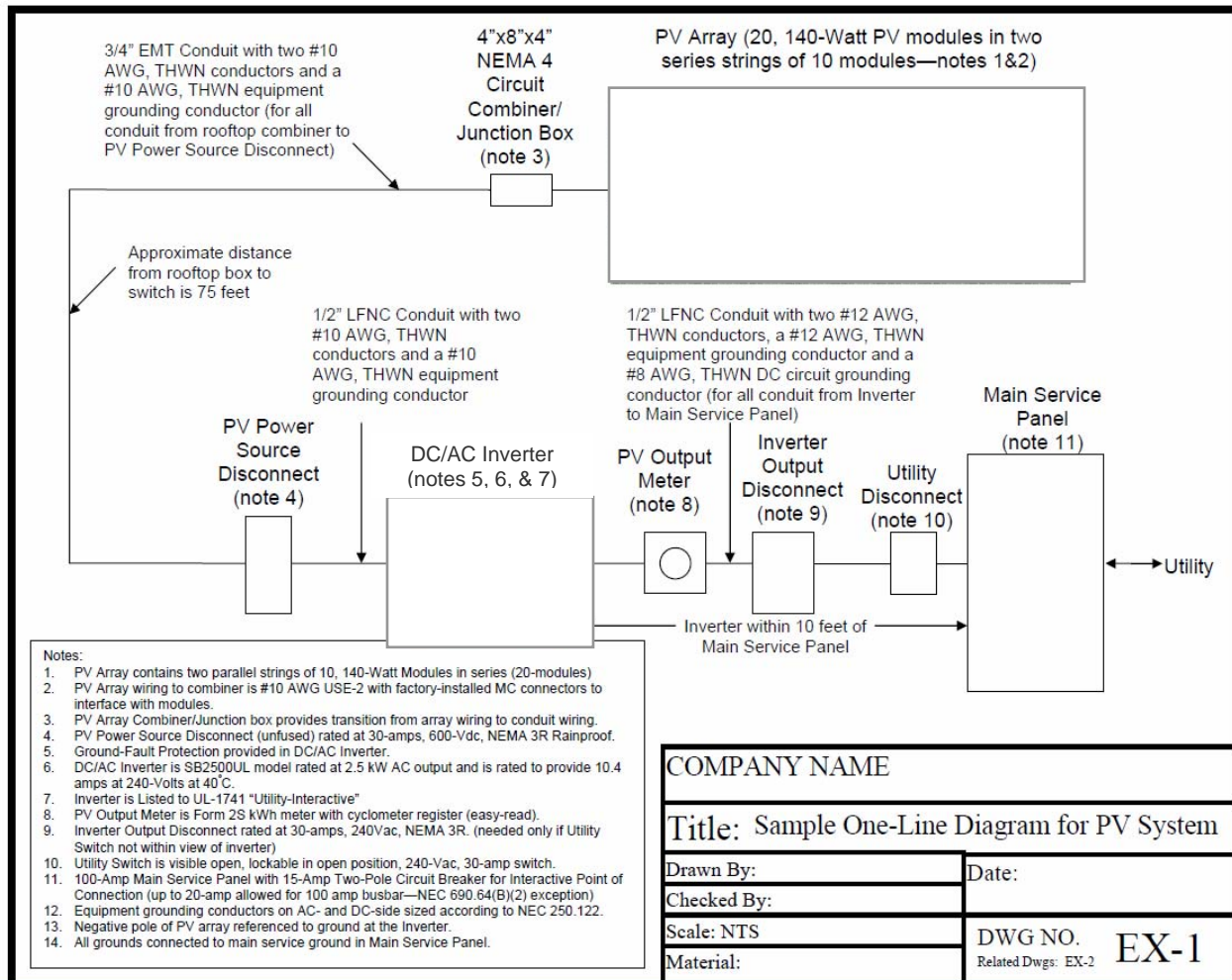
1. These diagrams are intended to be a means of identification for photovoltaic system components, circuits, and connections.
2. Disconnecting means and overcurrent protection required by Article 690 are not shown.
3. System grounding and equipment grounding are not shown. See Article 690, Part V.
4. Custom designs occur in each configuration, and some components are optional.

Figure 690.1(B) Identification of Solar Photovoltaic System Components in Common System Configuration.



Sample of Site Diagram





**Sample of One-Line Diagram**

## Worksheet for PV System - Plan Check

Supplied Diagrams:	Yes	No	Comments
Has a site plan been supplied			
Has applicant applied for building permit			
Has major equipment been identified on site plan			
Have the required electrical diagram(s) been provided			
Array configuration shown			
Array wiring identified			
Combiner/junction box(s) identified			
Conduit from Array to PV disconnect identified			
Equipment grounding specified-all devices/components must be listed for use			
Disconnect(s) identified			
Conduit from disconnect to inverter identified			
Inverter specified			
Conduit from inverter to disconnect to panel identified			
System grounding specified-all devices must be listed for use			
Point of attachment method identified			
<b>Inverter Information:</b>			
Are cut sheets provided			
Inverter model number specified			
Is inverter listed for utility interactivity			
Is equipment listed and rated for use specified			
Maximum continuous output specified			
Inverter input voltage range specified			
<b>PV Module Information:</b>			
Are cut sheets provided			
Are the modules listed/rated			
Has the open-circuit voltage from the listing label been provided			
Has the maximum permissible system voltage from the listing label been provided			
Has the short circuit current from the listing label been provided			
Has the maximum series fuse/overcurrent device been specified			
Has maximum power at standard test conditions been specified			
Has the maximum power voltage been specified			
Has the maximum power current been specified			
<b>Array Information:</b>			
Specified number of modules in series			
Specified number of parallel source circuits			
Specified total number of modules			
Specified operating voltage			
Specified operating current			
Specified maximum system voltage			
Specified short-circuit current			
<b>Wiring and Overcurrent Protection:</b>			
Is wire type rated at least 90°C			
Are conductor ampacities sufficient			
Specified maximum PV source circuit current			
Specified minimum source circuit conductor ampacity			
Specified minimum output circuit conductor ampacity			
Specified inverter output circuit conductor ampacity			
Is source circuit overcurrent protection sufficient			
Is the inverter listed for no back-feed current			
Is the inverter output circuit overcurrent protection sufficient			
Does the point of connection meet requirements of 690.64			
Has the point of connection panel busbar rating been specified			
<b>Information for Roof Mounted Systems:</b>			
Do the array conductors run through the structure			
If so, have protection methods been specified			
Has the array weight been provided			

## Photovoltaic Field Inspection Checklist

Electrical permit #\_\_\_\_\_

Building permit #\_\_\_\_\_

Premises address:\_\_\_\_\_

Date of inspection:\_\_\_\_\_

Inspector:\_\_\_\_\_

	Yes	No	Comments
Are the installation photos on site			
Are permit documents and plans on site			
Do the PV module model numbers match plans and cut-sheets			
Are the modules properly grounded per cut-sheets			
Does the array layout and associated wiring match plans			
Are cables and conduits properly supported			
Are all plug connectors used in the array fully engaged			
Does the inverter model number(s) match plans and cut-sheets			
Does the array support structure match plans			
If roof mounted, are all roof penetrations properly sealed			
If ground mounted, have the footings and structure been approved			
Are the required signs/labels durable enough for the environment			
Shock hazard warning label installed [690.5(C)]			
Shock hazard warning label, <i>ungrounded DC conductors</i> [690.35(F)]			
Sign identifying PV (DC) power source including the following: [690.53]			
Operating current (on plans)			
Operating voltage (on plans)			
Maximum system voltage [690.7]			
Short circuit current [690.8]			
Sign identifying AC point of connection including the following: [690.54]			
Maximum operating current (on plans)			
Operating AC voltage (on plans)			
Sign identifying disconnecting means for PV system [690.14]			
Sign at main service disconnect noting remote location of PV disconnect [690.56]			
Warning label for disconnect of <i>ungrounded conductors</i> [690.17]			
Sign for optional stand-by system [702.8]			
Signed <a href="#">Residential Photovoltaic Systems Installation Certification</a>			

## **PV Quick Design and Installation Reference/NEC 2008.**

Use Open Circuit Voltage as the Rated Voltage in the PV Source Circuit [690.7 (A)]

Voltages shall be  $\leq 600$  Volts [690.7 (C)]

Conductors and overcurrent devices shall be able to carry  $\geq 125\%$  of the short-circuit current of the source circuit [690.8 (B)(1)]

PV source circuit, inverter and battery conductors shall have overcurrent protection [690.9 (A)]

A SIGN (Marking), indicating the system operating voltage and current, the open circuit voltage, and the short circuit current, etc, shall be placed near the system disconnect point or as specified. [690.51 thru 690.56]

Grounded conductor to be white in color. [200.6]

Single conductor cable is permitted for module connections only; cable exposed to sunlight must be sunlight resistant. [690.31 (B)]

Modules shall be wired so they can be removed without interrupting the grounded conductor of/to another source circuit. [690.4 (C)]

Any wiring junction boxes shall be accessible. [690.34]

Connectors should be polarized and guarded to prevent shock. [690.33]

A means to disconnect and isolate all source circuits shall be provided. [690.13]

All ungrounded conductors shall be able to be disconnected from the inverter and all other equipment. [690.15]

If fuses are used, you must be able to disconnect the power from both ends (isolate). [690.16]

Switches should be accessible and clearly labeled. [690.17]

Live parts in Source and PV output circuits over 150 volts to ground shall not be accessible to other than qualified persons while energized. [690.7 (D)]

Ampacity and overcurrent device ratings in PV systems shall be considered continuous. [690.8 (B)]